

A Beach Probing System (BPS) for Determining Surf Zone Bathymetry, Currents, and Wave Heights from Measurements Offshore

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LONG-TERM GOAL

Our goal is to investigate, using both simulated and field data, the feasibility of using offshore measurements of the surface gravity wave field to remotely sense the inshore environment (hydrography, currents, and breakers).

OBJECTIVES

- To develop a data assimilation method (BPS model) for estimating the nearshore (shoreline to nominally 500m offshore) depth and alongshore-directed current profiles using offshore infragravity wave measurements. Extend the BPS model to estimate breaker type and surf zone width by assimilating wind-wave directional data.
- To develop a self-powered, self-recording, GPS-clock-accurate sensor package suite of three-axis current, pressure, and orientation sensors integrated into a semi-automated, near-real-time data acquisition, quality control, and analysis system for measurements of:
 - wind waves (0.04 - 0.35 Hz) and
 - infragravity waves (0.001 - 0.04 Hz).
- To test and evaluate the BPS model with both simulated and field (collected by the new sensor packages) data.

APPROACH

This is the end of the third year of a five-year program of concurrent development of the BPS model, the sensor package suite, and the data acquisition and analysis system. Field data collected at the end of the third year (Fall 1998 at Duck, NC), using the newly developed Sensor Packages, will compliment simulation data in the continued development and testing of the BPS model over the next two years. The Duck 1998 experiment was designed to test the capability of the BPS model for different sensor placements and environmental conditions. Two optional experiments, one to demonstrate the real-time processing and the other to investigate the ubiquity of infragravity waves on different beach genotypes, have not yet been activated.

The basic premise of the BPS modeling and data assimilation approach is as follows:

- Acquire data from an in-situ phase array of five to seven Sensor Packages offshore of the surf zone to directly measure the wind wave and infragravity wave directional spectra,

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- Apply inverse methods, and other data assimilation techniques, to estimate inshore of the array,
 - surf zone depth profile (hydrography)
 - surf zone alongshore current profile (magnitude and direction)
- Data fusion of the wind wave and infragravity wave spectral information with further modeling provides estimates of,
 - wave breaker height and type (spilling, plunging, collapsing)
 - surf zone width.

This project is multi-faceted and, as such, requires a breadth of knowledge and experience. Key personnel on this project from NorthWest Research Associates, Inc. are: Joan Oltman-Shay (a nearshore oceanographer, field experimentalist, and data analyst), Jim Secan (an ionospheric physicist, system software developer, and inverse modeler), Frank Smith (an electronics design engineer), Skip Echert (a field experimentalist), and Uday Putrevu (a nearshore theoretician and modeler). Key personnel consulting on this project are: John Booker (a geophysicist and inverse modeler from Univ. of Washington), Ed Boss (a system software developer from Sigma Solutions), Bob Bussey (a system software developer from Eagle Harbor Software), and Michael Clifton (a field logistic expert from Scripps Inst. of Oceanography, SIO). In addition, there is an advisory panel whose members were chosen to both advise on the technical approach of the project and on directions that may better serve the Navy if this technology was to transition. The members are: Barry Blumenthal (ONR), Dan Crute (CSS), Rob Holman (OSU), James Kaihatu (NRL-SSC), Steve Payne (SPAWAR), and Ed Thornton (NPGS).

WORK COMPLETED

We have successfully completed the following tasks:

- Sensor Package design, development, and testing in preparation for the Duck, NC field experiment
- Data acquisition, quality control, and analysis system design, development (up through wavenumber-frequency spectral analysis), and testing in preparation for the Duck, NC field experiment
- Two, 5-day-long field tests at Copalis beach, Washington (north of Gray's Harbor; Aug 1997 and April 1998)
- A six-week-long field experiment at Duck, NC (Sept - Oct, 1998)
- A study on how nonplanar topography influences infragravity edge waves
- Proof of the uniqueness of the infragravity edge wave dispersion relation for arbitrary depth profiles
- Demonstration that the infragravity edge wave dispersion is influenced by the presence of a submerged sand bar and that with perfect data, the dispersion relation data alone can be used successfully to resolve the presence of a sand bar.
- Demonstration that the infragravity edge wave dispersion can be used to resolve the cross-shore profile of alongshore-directed current.

RESULTS

Sensor Package Design and Tests (Echert et al, 1996; Oltman-Shay et al, 1998b,c):

After the Duck 98 (six-week-long) experiment, the Sensor Package is now a proven, robust design for deployment in depths of 2 to 10m. The Sensor Package operated both autonomously and with data

communication, and power to and from shore. The Sensor Package can therefore be deployed on a unsupported beach without an infrastructure of shore-based power.

The Sensor Package is a 'definite-purpose' package; it is designed to be an element in a high-resolution phase-array used to measure the wind and infragravity directional spectra. Each Sensor Package contains: a Sontek ADV0 (3-component Acoustic Doppler Velocimeter), a Setra 270 pressure sensor, a Precision Navigation TCM2 compass/inclinometer, an Onset Tattletale 8 (TT8) data logger/controller, a OAK 579 10 MHz Oven-Controlled Crystal Oscillator (OCXO), a Persistor 80MB flash memory card (>30 days of data), 27 alkaline D cells (4+ days of power, extended to 1 month power with external battery pack), an external port for power, communication, and synchronization with shore-base station if desired, an external port for an externally mounted sensor (e.g., temperature/conductivity sensor, altimeter, other).

As a result of our experience at Duck 98, a few minor design changes will be made (e.g., choice of cable plugs), but the total design remains essentially the same. A few enhancements are being considered. For instance, it would be advantageous to be able to download data to and from each Sensor Package using divers in place of the cabling to shore.

Data Acquisition and Analysis System Design and Tests (Secan et al, 1996,97; Oltman-Shay et al., 1998b,c):

The data acquisition and analysis system design has been partially tested at both the Copalis beach field tests and the Duck 98 field experiment. Onshore data acquisition was 100% at the Copalis field test (April 1998) and approximately 60% at Duck 98; the Sensor Package cable connectors are suspect. It should be emphasized, though, that Duck 98 data acquisition was actually 95% because of the on-package data storage.

The data analysis system can be used in both a near-real-time mode, when the deployment scenario affords a Sensor Package link to shore, or in post-analysis mode. The former was tested at both Copalis and Duck. Data were processed every 17 minutes, up through wind- and infragravity-wave directional spectra, with little or no intervention by scientists. The automated data-quality system was not implemented during these tests because it is not yet completed. However, the data quality was excellent at both experiments so that the absence of automated data quality control was not a hindrance. The automated analysis system development will continue over the next year to include data quality control and analysis up through the BPS model.

Copalis Beach, WA Field Test (Oltman-Shay et al., 1998a):

The April 1998 Copalis field test was designed to test a full array of Sensor Packages (seven) and the concomitant near-real-time data acquisition and analysis system. However, an experiment of opportunity also presented itself with the coordination of our field test with the Washington State Department of Ecology (Ecology) bathymetry surveys (Kaminsky et al, 1997; Ruggerio and Kaminsky, 1998; Cote et al, 1998). These surveys consisted of both dry-land surveying, using a GPS-equipped vehicle and shallow-water/surf zone surveying, using a GPS-equipped jet ski (Beach et al, 1996).

The Sensor Packages were deployed at low tide and acquired data at high tide with 2.5m of water covering the Sensor Packages. The beach is low-sloping (1:60) and dissipative; the observed wind wave field was always saturated. A longshore current in 3m depth of 30cm/sec was typically observed. Both infragravity edge waves and shear instabilities were observed in the processed data. The latter was a surprise since the depth profile from low to high tide (300m) was observed to be

planar. However, a few days into the experiment, Ecology ran the offshore jet ski surveys and found the presence of a 2m-high sand bar, 800m offshore (Figure 1). What we had thought to be a classic planar depth profile was in fact a large-scale bar-trough profile.

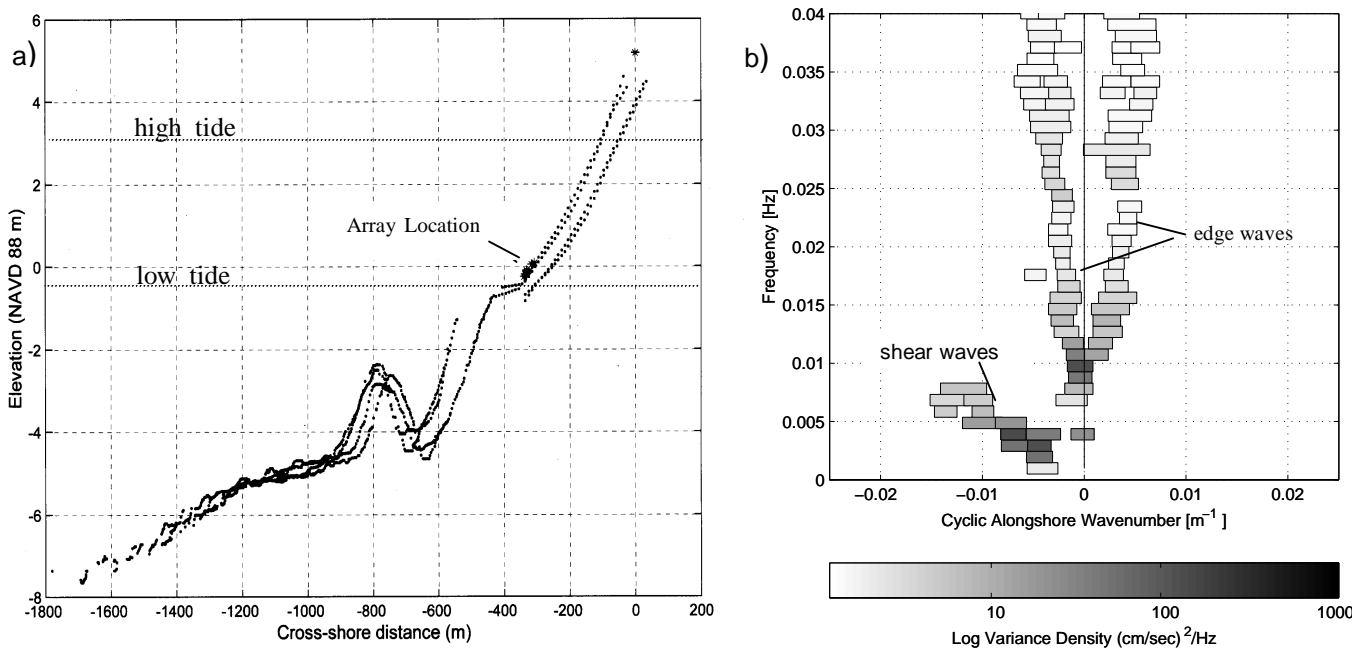


Figure 1. a) Several cross-shore depth profiles spanning the 360m alongshore placement of the array Sensor Packages, b) Wavenumber-frequency spectrum (fountain plot) showing the presence of edge waves and shear instabilities. Note the scales of the sand bar and the shear waves.

BPS Model (Putrevu and Oltman-Shay, 1998; Putrevu et al., 1998):

A study on describing nonplanar-topography influence-functions on infragravity edge waves was published. An unexpected result of this study was our new appreciation of the sensitivity of higher mode edge waves to shoreline bathymetric features; even though high modes have larger cross-shore scales than lower modes, they were shown to be more sensitive to shoreline shapes, such as foreshore steepening. A more detailed description of this work is presented in the “Wave and Current Dynamics” (Oltman-Shay and Putrevu) program in this annual report.

A surprising result of our investigation of the BPS model, and the application of inverse methods to estimate depth profile from infragravity edge wave observations, was the proof of the uniqueness of the infragravity edge wave dispersion relation for arbitrary depth profiles.

In our continuing study of the BPS model method and approach, we analyzed the behavior of the BPS inverse model with perfect (infragravity wave) data and found that the infragravity edge wave dispersion relation alone contains information about the presence of a sand bar. Therefore, in an ideal situation of perfect data, there is enough information to estimate a barred depth profile (Figure 2). Of course, real data will suffer degradation of the profile because of noise and other uncertainties. However, there is additional information in our measurements that can and will be included in the BPS inverse model; resolution of sand bars by the BPS model looks very promising. In addition to the ability to estimate the presence of a sand bar, we found that the infragravity edge wave dispersion data can also be used to resolve the cross-shore profile of alongshore-directed current.

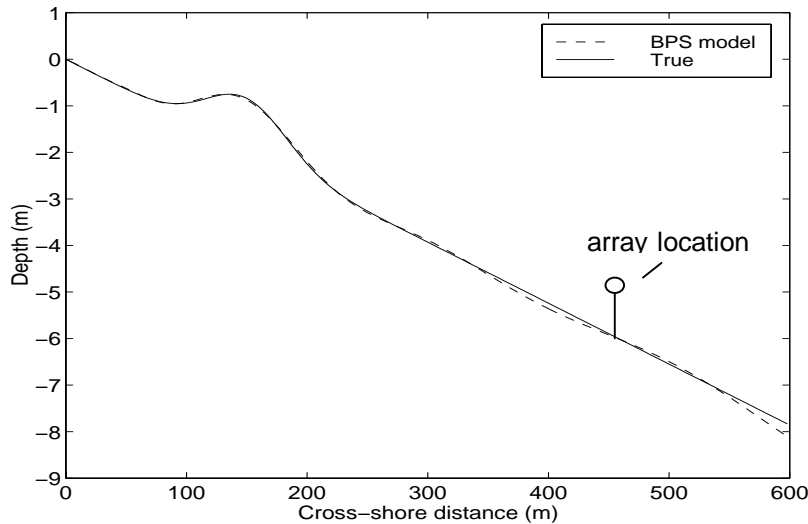


Figure 2. True and predicted (BPS Model) depth profile in an idealized case of perfect infragravity wave data assimilated into the inverse model.

IMPACT/APPLICATION

Sixteen Sensor Packages and two automated data acquisition, quality control, and analysis systems have been developed. This field system is designed for acquisition of wave and current data in the harsh environment of the nearshore (1m to 10m depth). The Sensor Packages can be deployed autonomously (self-powered and recording) or linked to shore. In either mode, the accurate on-board clock in each package insures synchronous data acquisition between packages and other instrumentation.

The potential application of the BPS model is broader than the long-term goal of measuring surf zone environmental conditions from measurements offshore. For instance, an unexpected application of model for scientists is the estimation of the cross-shore profile of alongshore-directed current from an alongshore-aligned array of sensors. The estimation of alongshore current profiles can come in handy in cases where deployment of a cross-shore array of sensors is prohibitive, either due to the expense or because of logistical difficulties. We will be using this capability to model and analyze shear instability waves on Copalis beach. The shear waves were observed by an alongshore array of Sensor Packages; a cross-shore array was not deployed to measure the profile of the mean alongshore current. However, by measuring the infragravity waves and using the BPS inverse model, we can estimate the cross-shore profile of alongshore-directed current that spawns the shear waves and therefore move forward in our model/data analysis of shear waves.

Another potential benefit of the BPS model will be its application in the study of edge wave mode mix. A fundamental question about edge wave dynamics is the relative amounts of modal energy. This knowledge is important to the predictive modeling of these waves (generation and dissipation). The BPS model lays the foundation for the type of model/data analysis that is required to answer this question.

TRANSITIONS

Because the Sensor Packages are robust and autonomous, they are attractive tools for inexpensive (no cable) deployments in the nearshore. Several of these instruments will be on loan to a project presently proposed to NSF by a group of nearshore oceanographers.

RELATED PROJECTS

“Nearshore Wave and Current Dynamics,” Joan Oltman-Shay and Uday Putrevu, ONR Coastal Dynamics

“Southwest Washington Coastal Erosion Study,” George Kaminsky, Washington Department of Ecology, Coastal Monitoring and Analysis Program

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